

DOES UTILITY SPENT NUCLEAR FUEL STORAGE AFFECT LOCAL PROPERTY VALUES?

WITH FEDERAL POLICY APPARENTLY FORCING MORE UTILITIES TO STORE THEIR SPENT NUCLEAR FUEL AT THEIR REACTOR SITES FOR THE FORESEEABLE FUTURE, WILL RESIDENTIAL SALE PRICES BE AFFECTED BECAUSE OF PUBLIC PERCEPTIONS OF RISK AND NEGATIVE IMAGERY?

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In December 1996, the U.S. Department of Energy formally notified the nation's nuclear utilities that it could not meet a Congressionally mandated and U.S. Court of Appeals-affirmed deadline of 31 January 1998 to begin removing spent nuclear fuel from utility reactor sites. If the spent fuel cannot be removed from on-site, water-filled storage pools, then aboveground, dry-cask storage facilities [independent spent-fuel storage installations (ISFSIs)] will have to be constructed at all 72 reactor sites in 33 states. Nine reactor sites in eight states are currently storing spent fuel in dry-cask facilities, with ten more sites indicating plans to use dry storage for spent fuel in the near future. The 105th Congress will be reviewing a variety of legislative options, including building an interim storage facility, expediting the process of siting a geologic repository, and helping to develop ISFSIs at reactor locations.

The timing is tight for decision makers and policy makers, for by 1998, it is estimated that a quarter of the nation's reactors will have run out of space in their on-site pools. In what has become a highly contentious national debate, the technology necessary for achieving safe storage, transport, and permanent disposal of spent fuel is a relatively minor issue. Rather, the major impediment to resolving the spent-fuel problem is obtaining public acceptance and political

approval of federal policy. The outcome of this debate will affect the spent-fuel management decisions to be made by individual utilities, host states, and state utility regulators.

Health and environmental risks have been cited as central issues causing the public's concern over the siting of high-level radioactive waste (HLW) (including spent nuclear fuel) facilities and the transportation corridors serving them. Often, however, the basis for opposition to siting and transportation initiatives is the concern that stigmatization will develop in areas surrounding spent-fuel facilities and that it will have a significant adverse impact on local economies. This concern is based on two premises:

1. The public attaches an intense negative imagery to facilities, activities, and technologies associated with the words "nuclear" and "radioactive."
2. Events that are associated with nuclear energy may generate an exaggerated adverse economic response through a process psychologists refer to as "the social amplification of risk."

The State of Nevada has vehemently opposed the designation of the Yucca Mountain site as the sole location for a repository site-characterization and suitability study, often referring to the extreme vulnerability of its tourism-related industries as the basis for opposition. The state legislature, in a 1989 resolution, when it refused the placement of a repos-

itory in Nevada, cited the argument that the Nevada economy depends on tourism and the perception of a safe environment. The State of Nevada subsequently filed an unsuccessful suit in the U.S. Court of Appeals for the Ninth Circuit to halt the repository on the basis of environmental and economic endangerment concerns and the unsuitability of the Yucca Mountain site. In 1995, the state legislature again passed a resolution reaffirming the opposition of the State to the permanent storage of HLW in Nevada and its opposition to the siting of an interim storage facility.

Concern over proximity to HLW has appeared elsewhere in the country. Other states (e.g., Texas, Utah, Wyoming, Tennessee, Washington, South Carolina, and New Mexico) have fought to keep both interim storage and permanent repository facilities from being sited within their borders because of their fears that their tourist and recreation industries, agricultural products, and state images would suffer significantly from the associated stigma. Efforts by a utility to construct aboveground, dry-cask storage facilities at Prairie Island in Minnesota met with citizen opposition, based partly on fears of declining property values, a loss of tourism, and the stigmatization of local farmland products. Concern over proximity to nuclear waste transportation routes has resulted in lawsuits for economic damages in New Mexico and Texas.

ESTIMATES OF ECONOMIC CONSEQUENCES

If studies that document perceptions of risk and negative images are any indication, opposition to federal HLW facility-siting and transportation programs, and probably opposition to future on-site aboveground facilities needed by com-

generation and storage activities at two nuclear power plants in California.

A major problem for researchers attempting to predict the economic impact of new nuclear facilities is that they are measuring the value of attributes that are not directly tradable in the marketplace. Unlike goods for which there are markets (such as land, property, agricultural

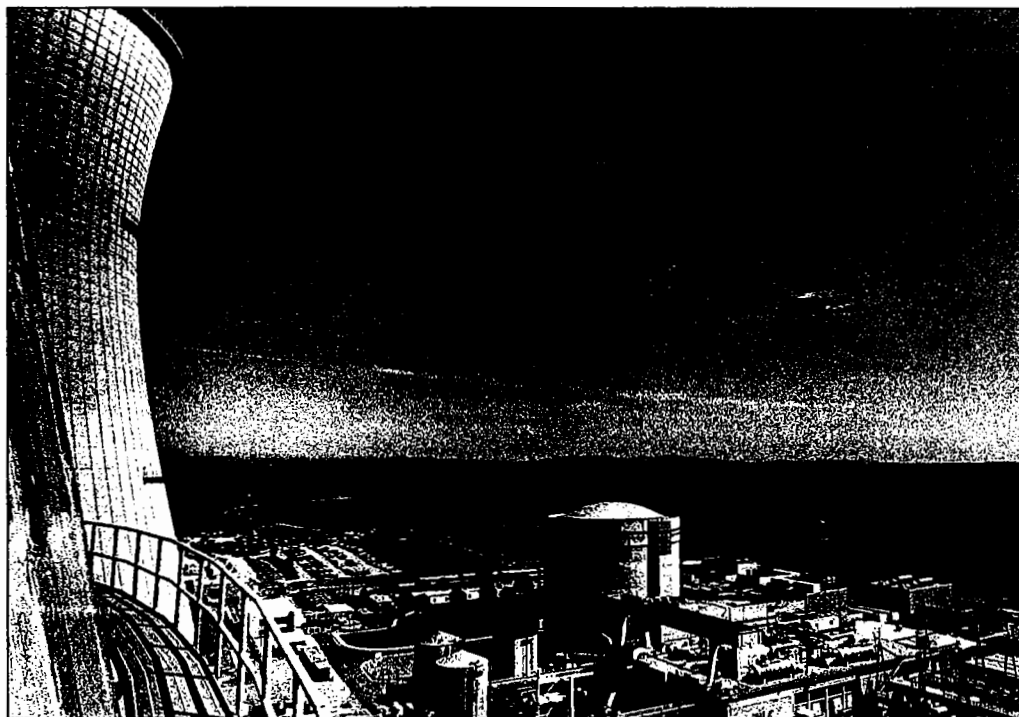
nuclear facilities. Survey findings reveal a high percentage of respondents who, when given a choice, consistently express an unwillingness to live, visit, or operate a business near nuclear-related facilities or transportation routes. In a recent study, for example, 40 percent of residents near three Midwestern nuclear power plants believed that the values of

homes within 50 miles would decrease, on average, by one-fourth if it were announced that spent fuel would remain on-site for the foreseeable future. Surveys also showed that almost half of the residents living near a reactor slated for decommissioning felt a high level of perceived risk over leaving the spent nuclear fuel on-site in dry-cask storage. The majority of survey research suggests that the public's perception of risk and fear of stigmatization appear to accompany decisions regarding the siting of spent-fuel facilities (whether an ISFSI at a reactor site, an interim-storage facility, or a permanent repository) and the transport of HLW.

With regard to the indirect technique, there has been very little research done on the economic impact of risk perceptions related to nuclear fa-

cilities (i.e., observed behavior). The ANL research program is intended to help fill this gap by generating information based on the systematic observation of economic responses to various spent-fuel-related events at nuclear facilities. We focus on the relationship between changes in residential property values and different spent-fuel storage scenarios at two nuclear power plants in California.

Property values are very sensitive to changes in surrounding land uses, especially when new land uses are unpopular and perceived as hazardous to the environment and to human health. Changes in property values can serve as accurate indicators of concern during the process of building an unwanted and hazardous facility, from the rumor of its possible siting through its construction and into operation. An examination of changes in property values can therefore indicate the link between people's perceptions of risk and the potential for adverse economic impact from HLW storage, transportation, and disposal.



The Rancho Seco nuclear power plant

mercial utilities as well, can be expected to continue. Despite the seeming intractability of the overall spent-fuel problem, a more workable federal policy on HLW is possible. An important step toward this goal is to understand and explain the differences between the claims of potential significant economic consequences of HLW facility siting and what evidence there is of actual economic impact. When federal HLW management programs are able to directly address public concern in a balanced manner by presenting economic measurements of the impact that can be expected, then they will be in a better position to discuss acceptable monitoring and mitigation programs with host jurisdictions and the public.

The potential for a significant adverse impact on residential property prices is often cited as a major concern by local citizen groups and political opponents. This article presents the findings of recent studies conducted at Argonne National Laboratory (ANL) on the relationship between changes in residential property values and continued spent-fuel

products, and consumer durables), the value of nonmarket goods (such as neighborhood characteristics, pollution controls, nearness to a central business district, and proximity to an existing or proposed nuclear facility) are only realized through the value established for other closely associated goods, such as land or property.

Two general types of economic measurement techniques, direct and indirect, have been used by researchers to estimate values attached to the characteristics, or amenities, of a particular location. Direct (survey-based) techniques solicit responses to hypothetical situations or word associations presented to individuals in telephone interviews or mail questionnaires. Indirect (market-based) techniques usually analyze observed behavior by using economic models to interpret historical data describing individual and group choices.

Direct techniques have been used by researchers to collect a large volume of local, regional, and national survey data on public opinion regarding proximity to

CALIFORNIA PLANT CASE STUDIES

We examined data on real estate sales in the vicinity of the Rancho Seco plant (near Sacramento) and the Diablo Canyon plant (near San Luis Obispo). California was chosen for the research primarily because of the quality and consistency of real estate sales data for the state (see the next section) and because the state is known for its stringent environmental legislation and citizen awareness of environmental issues. For example, in 1976 the California legislature passed a moratorium on the construction of new reactors until a demonstrated technology or means for disposing of HLW was developed. Currently, controversy surrounds the possible siting of a low-level radioactive waste disposal site in the state.

Both plants have also received attention in the local media. Rancho Seco was one of the first nuclear power plants to be closed, following a public referendum on ceasing operations, because the plant was no longer able to generate competitively priced power. It was also one of the first to propose aboveground dry storage and is now among 12 in the nation that have constructed or are constructing a dry-cask storage facility. Diablo Canyon has encountered some degree of local opposition since its inception, and media attention continues as a result of minor safety violations that occurred at the plant during recent reactor refueling. A recently proposed extension of the plant's generating license to 2025 was opposed by a number of local community groups, and there is some concern over what will happen to the spent fuel beyond 2007, when pool capacity is reached.

The plants vary as to the extent of their importance as sources of employment and income in essentially rural locations. Employment at the Rancho Seco plant stood at almost 500 when it was shut down in 1989, and it now employs approximately 150 people. Diablo Canyon employs 1800 people and provides substantial property tax revenues to the local county, cities, and school districts. Rancho Seco, on the other hand, is owned by the local municipal utility and has therefore been exempt from property taxes.

REAL ESTATE DATA USED IN THE ANALYSES

We used data on sales of individual single-family residential homes for a 5-year period (1990-1994) for a 25-mile area surrounding each plant. A data set on sales within a 15-mile area was also created to measure effects closer to each plant. These data were made available by TRW REDI-Property (TRW), which collects data on residential property sales from recorded deed transfers and local tax documents. The data contain detailed information on a wide variety of housing characteristics known to influence property values. Geographic location is also provided in latitude and longitude as derived from property addresses. The geographic information systems (GIS) software Mapinfo and ScanUS were used to calculate distances from each property sold to specific entities with a potential influence on property values, such as employment centers, highways, airports, Superfund sites, and the two nuclear power plants, and to assign the characteristics of a school district and census tract to each property.

Data were initially screened to eliminate properties for which data on the sales price and address were incomplete. Properties with a real sales price of less

than \$10 000 (which could indicate that the transaction was not "arm's length" and at market price) or more than \$400 000 (where there were likely unmeasurable unique qualities in properties) were also eliminated. Housing price data used in the analyses were representative of the properties sold within a 25-mile area around each plant.

Data were divided into two submarkets, an above-median and a below-median sale price submarket, for both the Rancho Seco region and for the region surrounding Diablo Canyon. This separation was necessary because prices for properties at the low end of the local real estate market may be influenced by factors different from those affecting higher priced properties. The median price for housing in the Rancho Seco studies was \$121 280 for the 25-mile area and \$134 753 for the 15-mile area. At Diablo Canyon, the median price was \$157 425 for the 25-mile area and \$163 357 for the 15-mile area. Properties sold within 15 miles of Rancho Seco tended to be newer, slightly larger, offered more rooms, and were situated on much larger lots than those farther away. For Diablo Canyon, properties closer to the plant were a little older, slightly smaller, offered fewer rooms, and were situated on substantially smaller lots.



The Diablo Canyon nuclear power plant

| Structural Characteristics ^a | Neighborhood Attributes |
|---|--|
| Age of property | Commute time ^b |
| Number of bedrooms | Race/ethnicity (percent) ^b |
| Central air | Occupancy status of housing (percent) ^b |
| Fireplace | Population density ^{b,c} |
| Number of full bathrooms | Public assistance (percent) ^b |
| Number of half bathrooms | Teacher-student ratio ^b |
| Number of stories | Sacramento/ San Luis Obispo address ^a |
| Lot size | Tax rate in 1994 ^a |
| | Distance to other activities ^d |
| | Earthquake risk ^e |
| | Ozone concentration ^f |
| Source: ^a TRW. ^b 1990 Census of Population and Housing. ^c Used as a proxy variable for congestion and crime. ^d "Activities" include railroads, Fort McClellan and Mather Air Force Bases, Morrow Bay power plant (coal fired), Superfund sites, interstate highways, ocean, lakes, rivers, and airports. Calculated using GIS software. ^e Risk Management Associates. ^f U.S. Environmental Protection Agency. | |

Table 1. Variables Used in the Analysis

HEDONIC MODELING

A primary challenge for housing analysts is to disentangle the influence of the plethora of factors that may affect residential housing values. For example, housing prices are most certainly influenced by the following: the structural characteristics of the property (e.g., number of bedrooms, number of full and half bathrooms, and age of property); the features of the neighborhood (e.g., proximity to hazards, access to amenities, and sociodemographic characteristics); and time, which primarily influences housing prices through the effect of business cycles. If one is to determine whether residential property markets are influenced by the presence of HLW storage, it is important to attempt to account for as many of these other influences as possible.

The hedonic model developed in this ongoing research views a unit of housing as being composed of a bundle of characteristics related to the features of the structure itself, the features of the neighborhood in which the structure is located, and the time at which the property sold. Each underlying feature can either add, subtract, or have no influence on the

overall value of the property. Regression analysis is employed to determine whether each of these features has a statistically significant influence on the real sale price (we employ the 95 percent level of confidence as our definition of statistical significance) and if they do, the magnitude of the influence. If significant influences are found to exist, the influence of the feature on the sale price of a property can be conceptualized as an implicit price. In other words, although explicit market prices do not exist for an additional bedroom or full bathroom, these features are implicitly valued because a house that has one more bedroom will sell for a higher price, other things being equal, than a house with one less bedroom. Likewise, one can derive implicit prices for neighborhood features, such as proximity to nuclear power plants.

Research based on the use of hedonic models to determine the effect of transmission lines, incinerators, landfills, airports, and earthquake hazards on property values have generally revealed some effects caused by perceived risk. These effects are usually very localized, with economic effects tapering off approximately 3 miles from the facilities. Few analyses of property values in the vicinity of nu-

clear reactors have been undertaken. However, analysis conducted after the accident at the Three Mile Island plant indicated that property values did not experience either an absolute decline or a slower appreciation rate. No empirical research has yet analyzed property value changes in response to the announcement, construction, or operation of spent-fuel storage and disposal facilities.

Although hedonic models can yield important insights about the relative importance of various local features on residential home values, they have often had serious shortcomings. Specifically, many hedonic studies have focused on a limited number of determinants (both structural and neighborhood), and they have not been precise in matching the neighborhood variables being evaluated to the property sale. We were careful to avoid these problems in three important respects:

1. The TRW data provide a substantial amount of detail about the structural features of the properties.
2. We used an extensive list of local neighborhood attributes.
3. By employing GIS software, we were able to precisely match location-specific neighborhood data to individual property data.

In our research, we established four broad groups of features that might influence real sales prices:

1. structural characteristics
2. neighborhood attributes
3. time factors
4. nuclear factors.

Table 1 lists the variables used to describe *structural* characteristics and *neighborhood* attributes.

We evaluated the potential impact of the various influences on residential property values, including nuclear facilities, by measuring the distance of each property sale from each of the activities. This price-distance relationship is commonly referred to as the housing-price gradient, and for the two nuclear power plants, it shows how residential sale prices change (in percentage terms) with proximity to each plant.

A *time* variable was included in the analysis to reflect the effect of cyclical real estate trends. The California real estate market experienced a deep recession during the early 1990s and has only recently begun to improve.

The *nuclear* variable includes the number of paragraphs in the local newspaper covering general nuclear issues and developments in nuclear waste storage at each plant. Data for these variables were

interacted with distance of the property from the plant to allow for changes in the housing-price gradient as a result of new public information about each plant.

ITERATIVE HEDONIC MODELING

We applied our hedonic models first to a 25-mile area around each plant. Next, we defined a set of more focused 15-mile areas to further research the nature of the housing-price gradient in the vicinity of each power plant. We were particularly interested in the impact of distance and news coverage variables. An overview of the results of these analyses is presented in the following discussion.

25-MILE ANALYSES

Hedonic models were used to analyze the screened property sales data within 25 miles of the two plants for the 5-year period. There were 1428 properties in the Diablo Canyon study area and 2508 property sales records in the Rancho Seco study area. Four regressions were run, one for each submarket for both the Rancho Seco and Diablo Canyon areas.

The model findings for housing sales in the Rancho Seco area show a statistically significant house-price gradient that was nonlinear (i.e., the surface was U-shaped). Specifically, after we controlled for *structural* and *neighborhood* features and after we accounted for the influence of the California recession, the housing-price gradient generally fell with distance from the plant, with the minimum point of the gradient occurring somewhere between 16 and 20 miles from the plant. In some ways, this proximity premium finding is surprising. One might expect proximity to the plant to be important where the plant is a large employer in the community (i.e., workers prefer shorter commutes). However, employment at Rancho Seco has diminished substantially since the plant shut down in 1989.

The model findings for housing sales in the Diablo Canyon area were not statistically significant for variables in the *nuclear* category, once *structure*, *neighborhood*, and *time* variables were controlled. The housing-price gradient was shown to be relatively flat for both housing submarkets. The findings suggest that the plant did not exert a significant upward or downward influence on properties selling in the area, once other factors were controlled.

Overall, the general pattern of these

housing-price-gradient surfaces for the 25-mile analyses calls into question the claim, based on direct techniques, that the generation, storage, and relocation of spent nuclear fuel significantly stigmatizes a region and has lasting impact on the property market and other economic activities. In addition, the finding of a housing-price premium in the vicinity of Rancho Seco suggests the need for a more detailed analysis for properties within 15 miles.

15-MILE ANALYSES

An analysis of the full complement of screened property sales data within 15 miles of the two plants for the 5-year

period was performed. The properties in this more restricted study area included only a third (765) of those used in the 25-mile Rancho Seco analysis and slightly more than a quarter (400) of those in the Diablo Canyon analysis. The majority of houses sold were located at distances greater than 8 miles from the plants because of the presence of large buffer areas and agricultural land around each plant. Figures 1 and 2, showing the actual real sales price of residential properties over the 5-year period for 15 miles around each plant, reveal no obvious patterns.

The model findings for housing sales in the Rancho Seco area showed a statistically significant house-price gradi-

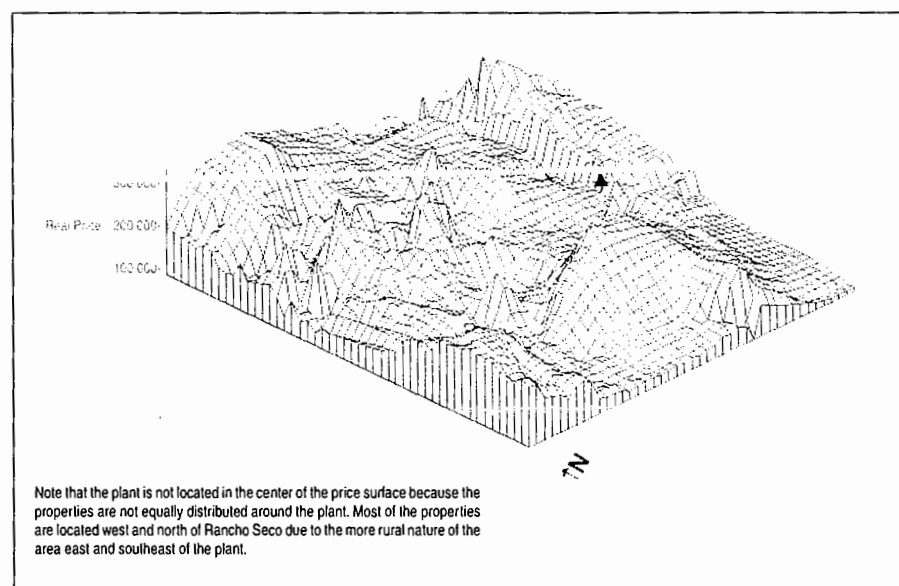


Fig. 1. Real estate price surface for all properties in the sales sample (1990-1994) around Rancho Seco (15-mile radius).

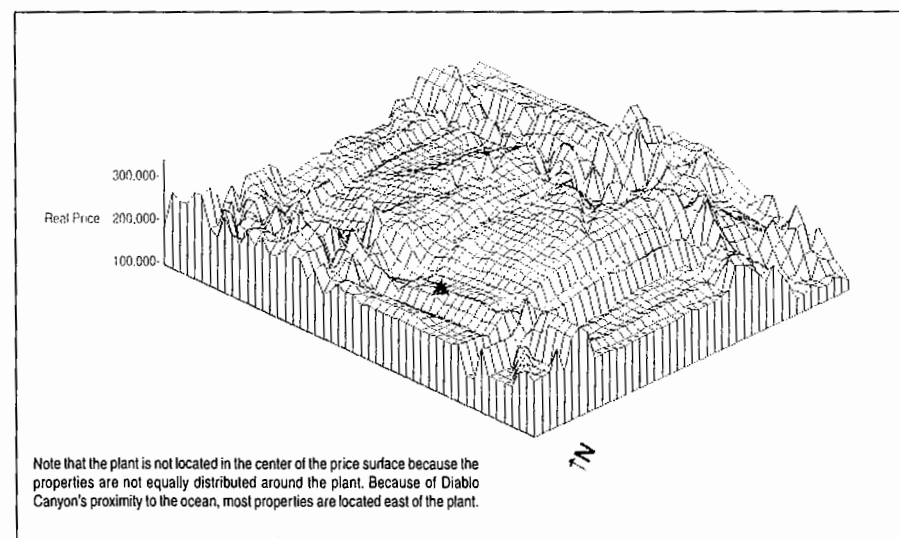


Fig. 2. Real estate price surface for all properties in the sales sample (1990-1994) around the Diablo Canyon plant (15-mile radius).

ent in the above-median submarket, and they revealed a pattern different from that depicted in the 25-mile analysis. The housing-price gradient was an inverted U-shape with a peak at 8.3 miles, the location of the closest town. Specifically, when *structure*, *neighborhood*, and *time* influences were held constant, sale prices initially rose with distance from the plant and then fell thereafter. Thus, any aversion to the plant or activities at the plant appeared to dissipate after about 8 miles. It should be noted that only about 18 percent of the property sales data in the sample was within 8.3 miles of the plant (the average distance was 12.5 miles). Figure 3 graphically represents the pre-

NEWS COVERAGE ANALYSIS

Nuclear-related events that receive media attention are often cited as having the potential to precipitate a significant adverse economic impact because of the negative imagery and perceptions of risk these events may produce. We analyzed the effects of general news coverage of nuclear issues on property sales for the 25-mile area and the effects of newspaper articles in a number of topical categories within the 15-mile area.

The effect of general news coverage of nuclear-related issues on property sales within the 25-mile study areas was performed for both plants by using a

price gradient to change as a result of news coverage. During the 5-year study period, there were 70 newspaper articles on Rancho Seco and about 350 articles on Diablo Canyon.

The findings for Diablo Canyon properties were not statistically significant and thus showed no apparent influence from news coverage. The findings for the Rancho Seco 25-mile area were significant for the above-median sample. For the vast majority of sales in this submarket, the findings indicated a decreasing aversion to proximity to the plant as a result of public news coverage.

A more detailed assessment of the effect of nuclear-related newspaper articles on property sales for properties within 15 miles of both plants was then performed. Newspaper articles were separated into three topical categories (nuclear, spent nuclear fuel, and transportation of HLW). The number of articles related to a specific category was interacted with distance of the property from the plant, again to permit the housing-price gradient to change with increased news coverage. Results showed little conclusive evidence of newspaper exposure affecting property prices. The only exception was in the above-median sample for Rancho Seco. Here, additional articles on HLW actually reduced the aversion to the plant, moving the peak of the gradient 0.3 miles closer to the plant for an additional article. This is perhaps because residents may be less concerned with HLW now that the plant is permanently shut down. Each additional article on nuclear technology in general slightly increased aversion to the plant, moving the peak of the housing-price gradient about 0.2 miles farther from the plant.

Newspaper articles reporting announcements of current and future storage plans for the spent nuclear fuel located at both plants appeared in the local dominant newspapers during the 5-year period. The effects of these articles were specifically analyzed, again using a 45-day grace period built into the model, using the same rationale as discussed earlier.

The announcement date used for Rancho Seco was 14 October 1991, when the *Sacramento Bee* published an article, "Use Seco for Nuke Waste Idea Grows," describing that the utility was applying for a Nuclear Regulatory Commission license to construct and operate a dry-cask storage facility. The announcement date used for Diablo Canyon was 24 July 1992, when the *Telegram-Tribune* published an article,

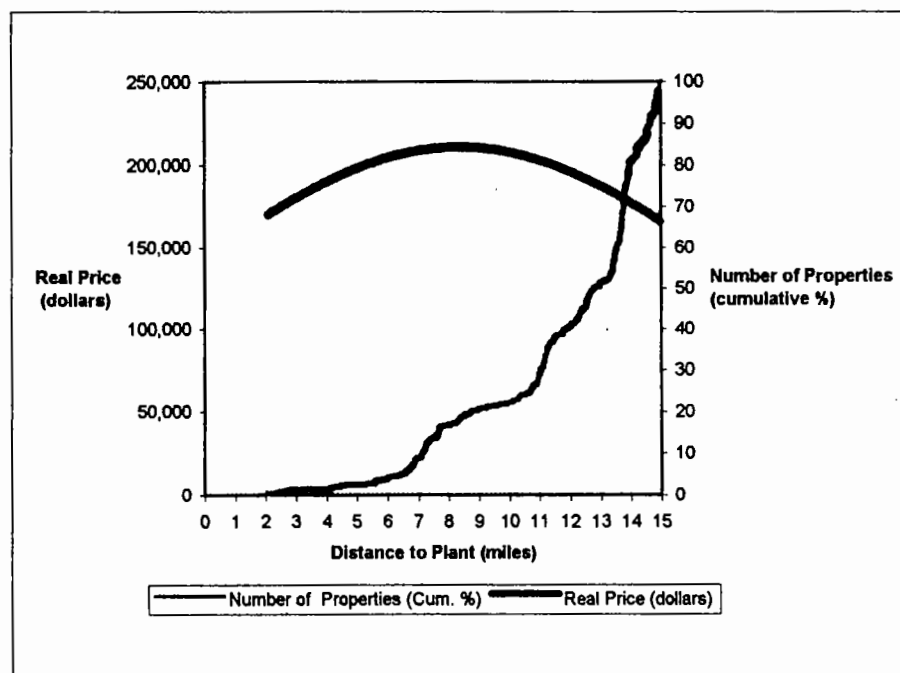


Fig. 3. Predicted housing-price gradient and location of properties in the above-median sales sample at Rancho Seco.

dicted housing-price gradient for the average property and distances from the plant of properties sold, for the above-median sample.

The model findings for housing sales in the Diablo Canyon area were not statistically significant for any of the distance-related variables in the *nuclear* category for either housing submarket. There were no single-family homes close to the plant, with the first property sold being 6 miles from the plant (the average distance was 9.8 miles). Strong employment effects may have affected property values around the Diablo Canyon plant, especially because its coastline location makes the study area a half circle.

news coverage variable in the hedonic regressions. The variable was defined as the number of paragraphs that appeared in the dominant local newspaper between 45 and 120 days before each individual sale. The time interval was chosen to represent the period prior to a sale in which news coverage was likely to influence prices offered by potential buyers. Public information disseminated within 45 days of the sale is assumed not to influence sale prices because it occurs after a contract on the property is signed and cancellation of the contract would involve substantial penalties. This variable was then interacted with distance of the property from the plant to allow the housing-

"Agency May Renege on Vow to Take Diablo Canyon Waste in 98," suggesting that dry casks might be placed at the Diablo Canyon site in the future because of DOE's announced position that it did not have an obligation to take the reactor's HLW starting in 1998. The issue of on-site, dry-cask storage received additional public attention 3 months later when facility operators applied to the NRC for a 15-year license extension to 2025.

When the announcement variable was interacted with distance, the results for both plants were statistically insignificant; thus, no effects on property values were apparent.

CONCLUSION

Our research used market-based techniques to interpret 5 years of historically generated property transaction data from around two California nuclear power plants. The goal was to assess actual individual behavior and choice in relation to a property's proximity to nuclear reactors where HLW storage was an issue. Regression results were found to be statistically significant for properties within 15-mile and 25-mile circles of the Rancho Seco plant, based on distance-related variables in the *nuclear* category; in other words, a premium was associated with proximity to the plant. There were no statistically significant findings on the effect of proximity to the Diablo Canyon plant.

In our analysis of the influence of general newspaper coverage, a very small number of property sales within 25 miles of Rancho Seco were found to reflect a statistically significant aversion to the plant. When the effects of specific published announcements about plans to store current and future spent nuclear fuel at the plants on property sales within 15 miles were analyzed, the results indicated only minor influences from media coverage. Indeed, the general shape of the housing-price gradient was unchanged. These results suggest that any perceived risk, negative imagery, or stigma that may exist is overwhelmed by accessibility effects associated with a desire to reside close to the workplace or other local economic or environmental influences. Extensions to the research could focus on investigating property value impacts in specific time periods, including postannouncement, preconstruction, and postconstruction.

In addition to more thoroughly analyzing temporal effects, property value effects at other reactor sites also need to be investigated.

A major challenge for policy makers and decision makers in their efforts to site temporary and permanent HLW facilities and select routes for HLW transportation is the need to balance survey evidence, which suggests that adverse economic impacts and stigmatization are likely to result, with findings of research using market-based techniques, which suggest that risk perceptions that may exist are not likely to be reflected in local economic behavior. Indeed, our research suggests that some individuals may actually be likely to place premiums on proximity to nuclear plants. Policy initiatives that attempt to anticipate public reaction and behavior with regard to HLW facility-siting options based only on research on stated intent and imagery would therefore likely overestimate the extent of the reaction in the local economies concerned.

The next couple of years will be a critical period in the debate over the impact of HLW facilities. Crucial to the resolution of the HLW debate will be reconciling the findings about adverse risk perceptions of individuals affected by HLW facilities and transportation found in surveys with the findings of market-based studies of the actual impact of nuclear facilities and programs on economic behavior. Indeed, the political and economic environments in which HLW facility-siting decisions are made may be ones in which there may not be any accompanying negative economic effect but in which there is significant political opposition. Only when policy makers and planners are able to respond knowledgeably on the basis of both survey and market-based studies will they be able to generate greater public dialogue, public acceptance, and political approval.

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